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THE TRANSMISSION OF PULSED LIGHT SIGNALS FROM SUBMARINES TO SURFACE SHIPS

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5 May 1954

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DEPARTMENT OF THE NAVY
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From: Commanding Officer, Naval Research Laboratory
To: U. S. Department of Justice, Assistant Attorney General
Civil Division, Commercial Litigation Branch

Subj: CHARLES E. PFUND V. UNITED STATES, COURT OF FEDERAL CLAIMS NOS. 276-87C AND 592-88C

Ref: (a) DOJ ltr 154-276-87/154-592-88 of 5 Jun 95

Encl: (1) NRL Memorandum Reports cover pages

1. Per reference (a), we have reviewed all the reports in the 5 June 1995 letter from Mr. Hunger and Mr. DiPietro.

2. The material contained in enclosure (1) describes measurements made relating to optical communication with submarines. The instruments and hardware used in the measurements is quite out of date and not in use currently. For example, the electronic circuits described employ vacuum tubes rather than solid state devices.

3. The measurements results do not reveal any operational details, but rather are descriptive of the instrument capabilities, the optical properties of water, and some atmospheric phenomenology.

4. None of the information contained in these reports requires any further protection.

5. In our opinion, every report itemized in reference (a) can be downgraded to UNCLASSIFIED and assigned a distribution statement A: Approved for public release; distribution unlimited.

CHARLES ROGERS
By direction

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THE TRANSMISSION OF PULSED LIGHT SIGNALS FROM SUBMARINES TO SURFACE SHIPS

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5 May 1954

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ABSTRACT

Previous field trips have been made using flash lamp sources and photo-electric receivers operating from underwater to air. Only vertical measurements were possible and these were made by operating the equipment from the deck of a surface ship. Recently a trip was made with the flash lamp mounted on a submarine and the receiver operating from a destroyer in a HUKLANT operation. A daylight-to-night run was made on 4 March with the submarine on a straight course and submerged to a depth of 150 feet. Contacts were made by the destroyer at distances from 150 to 200 yards. This experiment and others are discussed with reference to possible choice of wave bands for different conditions of operation in day and night transmissions.

PROBLEM STATUS

This is an interim report of a recent field trip taken in connection with this problem. Work on this problem is continuing.

AUTHORIZATION

NRL Problem N03-22
RDB Project NR 473 220

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INTRODUCTION

Previous experiments[1] by this group have been performed with pulsed light systems in coastal waters and in sea water. Besides the work of making more complete transmission studies of these waters, it has also been the object of recent experiments to investigate the feasibility of using underwater-to-air communication systems.

By using transmitter and receiver units lowered from the deck of a ship it has been possible to make many vertical measurements and to ascertain depths to which the equipment may be expected to operate under daylight and night conditions. As mentioned in a previous report[2], a very satisfactory depth of 375 feet has been reached even during operations while the sea was illuminated with strong sunlight.

The approach to the practical problem involves the selection of wavelength bands in the visible and near ultraviolet (black light) region of the spectrum to permit suitable tranmission depths and still have the signals invisible to the eye. A band in the 350 to 370 mμ region may be necessary for night operation, and, incidentally, sea water transmission in this region has proved to be reasonably good to depths at which a submarine ordinarily operates.

The improvements offered by the increase of peaked energies and shorter time durations of the light pulses are being realized with the development of high-energy flash lamps and newer discharge circuits. Light pulses with a half-peak time duration of somewhat less than a microsecond and a peak discharge power of six million watts are being used at present with the Mullard Type LSD-2 flash lamps.

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EXPERIMENTS FROM SUBMARINE TO SURFACE SHIP

In all the field trips including the August 1953 cruise from NRL around Key West to Panama City, Florida, the experimental work was confined to vertical measurements. Only recently have facilities been made available to make measurements directly from a moving submarine to other craft.

From 1-12 March 1954, a limited amount of work was performed during the HUKLANT operations out of Norfolk, Virginia. The transmitter unit was mounted outside the pressure hull of the USS COBBLER, and two experimental receivers were mounted on the USS SUMNER, a destroyer in the task force. No special equipment was developed for these tests since the apparatus from the previous trip was considered to be in working condition and could be easily installed on the submarine and destroyer.

A daylight-to-night run was made on the evening of 4 March to see what ranges could be expected from the apparatus. In spite of rough weather and the fact that the photoelectric pickup unit on the port side of the destroyer was inoperative, it was possible to get results that were significant enough for interpretation.

The test run was performed by having the submarine submerge to a depth of 150 feet and hold a straight course at a speed of approximately four knots. At the same time the destroyer followed a course back and forth perpendicularly to the submarine's path. The time of the run was from 1725 to 1848 hours with sunset officially given as 1734 for that day.

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Because the receiver was only 35 feet above the surface of the water (Fig. 1), it was possible to get pulse indications to a horizontal range of 150 to 200 yards from a point directly over the submarine. The signal strength within a circle of this range was very intense and a clearer picture of the geometry of the energy cone was obtained. At the receiver point R, on the edge of the 200-yd circle, the transmitted signal was barely detectable but inside this circle the signal was so strong that the receiver became saturated.

CHOICE OF WAVELENGTH BANDS FOR DAY AND NIGHT OPERATIONS

Although only a small fraction of the optical path of a ray as shown in Fig. 1 is through sea water, the loss in intensity is chiefly in this underwater transmission. The curves[3] of Fig. 2 illustrate how the attenuation of light by sea water varies with the wavelength. Toward the left of the wavelength scale in the ultraviolet region the attenuation becomes very high below a wavelength of 350 mμ, and toward the right in the infrared region the attenuation becomes so high that transmission is impractical above a wavelength of 625 mμ. The best transmission is in the blue-green region (lowest point of the attenuation curve), but this is also fairly high in the visible portion of the eye sensitivity curve[4].

The flash lamp can be operated at very intense peak emissions in the lower visible and near-ultraviolet regions, and the photoelectric receiver can also be made very sensitive in these bands. The theoretical and experimental problem then resolves itself into choosing a band (A to B) such that the signal will be strong and the visibility will be zero or

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practically negligible. Also the width of this band must be determined by the signal-to-noise ratio when the operation takes place with ambient illumination ordinarily due to sunlight.

The depth of 375 feet reported in the NRL Secret Progress Report (footnote 2) was obtained near noon, and a filter with a transmission near 470 mμ was used. The flash lamp could not be seen below 25 feet because of the strong reflection at the surface caused by the sun. For security in night operations the transmission band AB must be chosen as far down in the ultraviolet region as possible. But to maintain good signal strength in the conical field above the water, the band AB cannot be chosen too far down into the ultraviolet region. This is due chiefly to the fact that emission from the present flash lamps lacks energy in the 300 mμ region where the attenuation in sea water is relatively high.

FEASIBILITY OF USING PULSED LIGHT FOR UNDERWATER SIGNALLING

At the present time it may be said that any identification or communication system from submarine to surface ship is impractical in view of the ranges needed for most operations. Nevertheless it seems likely that some system between submarine and aircraft may be practical because of the larger area covered by the energy cone at medium to low flying altitudes. Reference to Fig. 1 will show that the transmission pattern is much more favorable to aircraft equipment than to equipment installed on surface ships.

PRESENT STATUS OF THE PROBLEM

A full and comprehensive report on the project is now in preparation. This will include descriptions of the equipment as well as a

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mathematical treatment of the problems involved such as amplifier band-widths and signal-to-noise ratios.

The equipment used on the HUKLANT operations is being modified to permit installation on a seaplane of the P5M type. At the next opportunity it is hoped that an experiment can be performed from a submerged submarine and a plane that is ordinarily equipped for patrol operations.

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REFERENCES

1. W. S. Plymale, Jr. and D. F. Hansen, "The Transmission of Ultraviolet Light Pulses in Sea Water," NRL Report 4021 ([redacted]), August 1952.

2. W. S. Plymale, Jr. and D. F. Hansen, "Ultraviolet Transmission of Sea Water," NRL Progress Report, Quarterly Secret Supplement, October 1953.

3. E. O. Hulburt, "On the Penetration of Daylight into the Sea," J. Opt. Soc. Am., 22, 7 (1932).

4. A. C. Hardy, "Handbook of Colorimetry," The Technology Press, Cambridge, Massachusetts, 1936.

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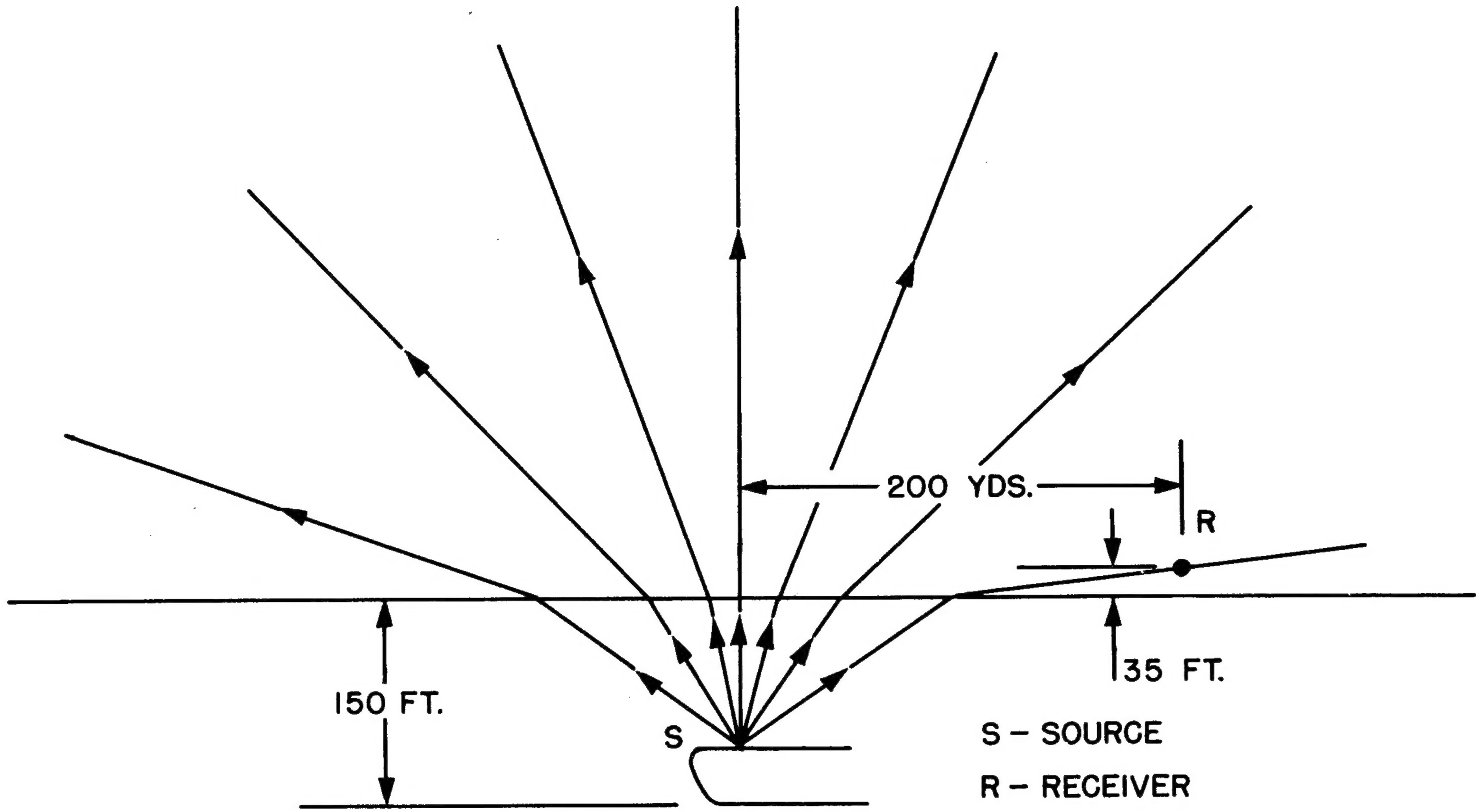

Figure 1 - Simplified Diagram of Transmitted Rays

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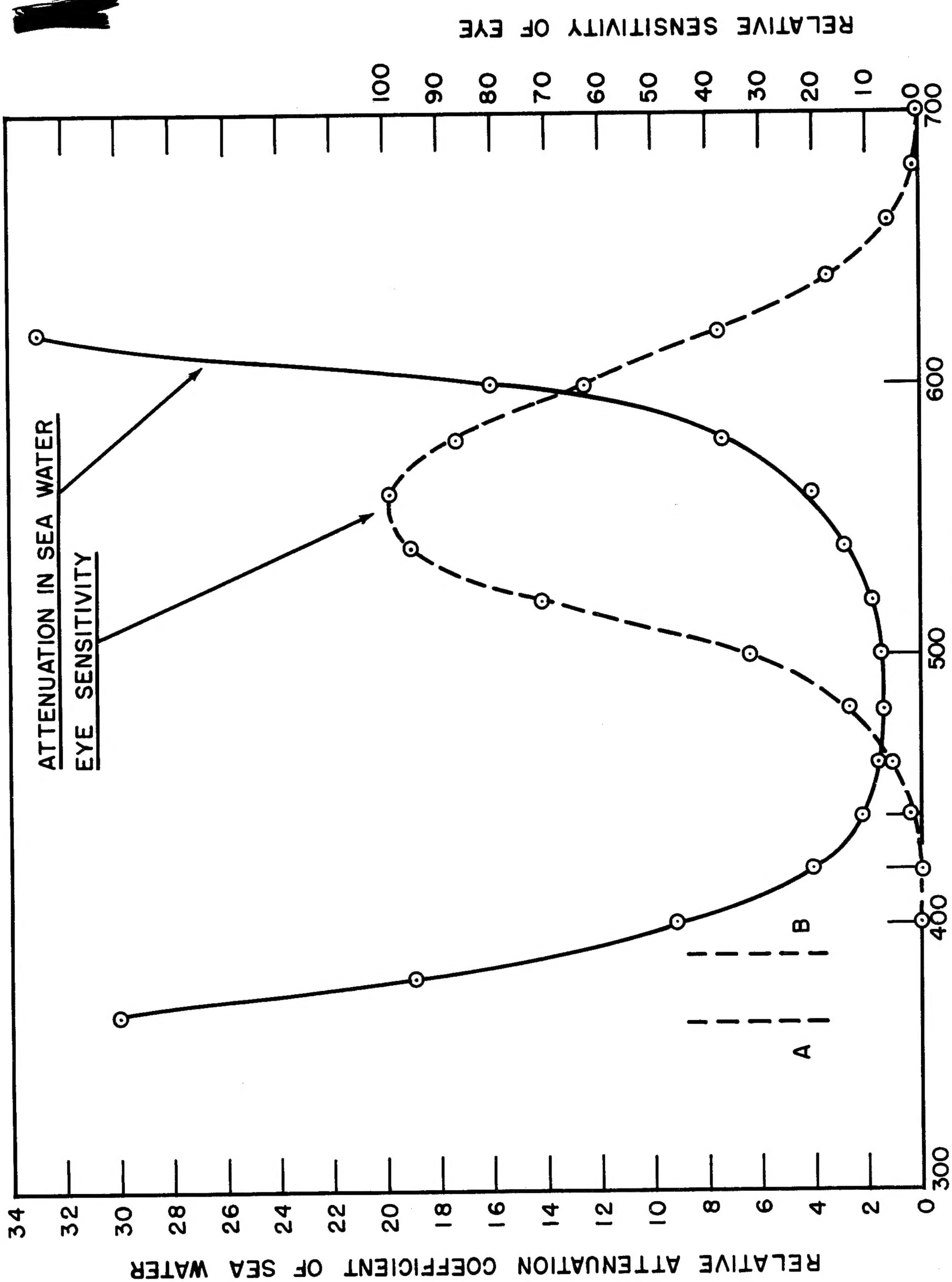

Figure 2 - Attenuation Curve of Sea Water Plotted on the Same Wavelength Scale with the Luminosity Curve of the Eye

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